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# WORKING CONDITIONS AT THE WATER TREATMENT PLANTS: ACTIVITIES, HAZARDS AND PROTECTIVE MEASURES

**Abstract:** *In operational sense, wastewater treatment plants and operators who work at those facilities present a proper basis for good water quality status. The basic aim of this paper is to assess the risk to which workers - water treatment operators - are exposed to within water treatment plants, as well as to propose preventive measures in order to reduce the level of occupational risk. The applied methodology consists of system analysis, with in-depth literature review. The usage of appropriate occupational safety systems in the water treatment control processes leads to a double effect: a higher quality of treated water in shorter periods of time, with energy and material savings, as well as safer and healthier working environment.*

**Key words:** water treatment plants, occupational hazards, occupational risks, protection measures.

## INTRODUCTION

At the European Union level, the Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council of 23th October 2000 establishing a framework for Community action in the field of water policy) was the first "framework" Directive. This Directive amended significant number of previous directives in the field of water policy (water protection, protection from water derived emergencies and water resources exploitation). Water Framework Directive aims at "good ecological status" for all ground and surface waters (rivers, lakes, transitional waters, coastal waters, and other water bodies) in the European Union by the end of 2015. This Directive imposes a set of differential criteria that should be met, particularly in the field of surface water quality intended for water supply, as well as for protection of water resources from anthropogenic pressure. [1] Majority of the provisions of the Directive aimed at water protection are transposed in Serbian Law on Environmental Protection and Law on Water, while the potable water quality standards are expressed by national regulation. The Serbian Law on Environmental Protection and Law on Water define measures and requirements for environmental and water protection. Some of the listed preventive measures are dedicated for water protection and, in general, water quality management. The application of the provisions leads to a reduction in emissions of greenhouse gases, the reduction of the amount of generated waste and reduction of water and soil pollution. [2, 3]

As regards the importance of potable water quality, Serbian potable water quality limits are within the limits of majority of physical, chemical, biological and radiological parameters. [4]

The operative tools which satisfy the need for good ecological status are centralized water treatment plants and water treatment operators within the facility. Besides the centralized water treatment plants, which are the focus of this paper, it is not less important to mention the small-scale pre-treatment facilities at the industry level, indented for wastewater pre-treatment before a discharge into a sewer system. [5] The overall aim of this paper is to analyze general occupational conditions in the water treatment plants, taking into account the nature of the activities of the enterprise and/or establishment. Also, the paper tries to evaluate the risks to the operators' safety and health, either in terms of choosing the work equipment, preparations and their chemical compositions, and the fitting-out of workplaces. Based on risk assessment results, the employer is obliged to assure the improvement of the occupational safety level by taking preventive measures or changing the working and productive methods if necessary.

## THE MEANING OF WATER TREATMENT

The required degree of potable water or wastewater purification is defined by appropriate positive legal measures (law, regulations and rules), while it is realized through various processes, i.e. different unit operations of wastewater treatment. Competent institutions control the implementation of these measures.

In practice, the determination of the required degree of water purification (either raw water or wastewater) (DWP) occurs according to three basic approaches (combined approach):

- By implementing the standard for the recipient (the emission standards) - determining the DWP based on the

required water quality in the recipient after mixing with the purified wastewater (a mixture of a fresh water and waste water from the municipal sewage systems). Purification is necessary in case of all pollutants, where the water in the recipient after mixing with the wastewater condition is not $C_M < C_{MAC}$ ($C_{MAC}$ represents maximum allowable concentration - MAC for recipient while the $C_M$ stands for possible concentration within the mixture of recipient and untreated waste water).

- By applying the effluent standards (or emission standards) - determining the DWP on the basis of the required quality of treated water, i.e. effluent without consideration of water quality in the recipient. In case of all pollutants where $C_{sw} < C_{efl}$ ($C_{efl}$ represents MAC for the effluent while $C_{sw}$ stands for concentration of raw sewage water), purification is necessary,
- By applying the potable water quality limits.

Design of plants for water treatment is an extremely complex problem and requires the involvement of experts from various fields:

- civil engineers,
- spatial planning engineers,
- technologists,
- demographers,
- biologists,
- mechanical engineers,
- measurement and control operators,
- electrical and electronics engineers,
- environmental protection and occupational safety engineers, etc.

A centralized plant for potable water production intended for domestic water supply and centralized waste water treatment plant should be designed in the manner appropriate to satisfy the needs in 15 or 25 years after the construction (similar to the capacity of a regional sanitary landfill).

## UNDERSTANDING THE WORKING CONDITIONS AT THE WATER TREATMENT PLANT

The occupational safety management system is a very complex, therefore, its performance can be described by a large number of indicators. [6] During the normal operation and maintenance of each production system, there are numerous situations that can trigger an accident. For this reason, it is very important to assess the possibility of occurrence of errors or error prone activities. [7, 8]

The term *occupational safety and health* (OSH) was introduced in Serbia in 2005 through enactment of the Occupational Safety and Health Law, and it represents an organized activity aimed at providing safe and healthy work and occupational safety conditions.

The law regulates the rights and obligations of employers and employees, the organization of OSH, record keeping, cooperation and reporting, supervision, and penalty provisions.

The term occupational safety and health is defined in Act 4, Par. 1, Item 4 of the Law:

Occupational safety and health is the provision of work conditions that will minimize occupational injuries, professional diseases, and work-related diseases, and that predominantly create prerequisites for full physical, mental, and social wellbeing of employees. The purpose of conducting operations in accordance with occupational safety is to raise the awareness within the organization about the importance of employee health and preventive activities. Any threat to employee safety needs to be predicted and identified for easier removal. By introducing and implementing an OSH system, the organization takes a proactive stance on prevention and employee safety. [9]

During the process of potable water conditioning or wastewater treatment due to minimization of its impact on the natural recipients, the employed in the facilities that deal with some of these treatments must perform a series of operations, laboratory and physical work obligations. These obligations also include the activities of the monitoring process of the plant, as well as constant monitoring of indicators of the technological process of water treatment and response in terms of committing the necessary modifications. Other important activities include maintenance of facilities and equipment, or for example work with sludge incinerators at installations for the treatment of used water. During the performance of work activities, employees at these plants were subjected to a series of hazards including noise, moving mechanical assemblies, sources of electricity, chemicals, gases, vapors, aerosols, fog and poor ventilation, the movement in different levels as well as work in confined spaces such as tunnels and pipes, etc. The above-mentioned operations should be, due to these dangers, conducted under the supervision of the person responsible for safety. The information obtained via supervision should be used to improve security procedures.

Professional risk management at water treatment plants (both potable and wastewater) is a very complex issue that need to be analyzed from several aspects. Further, it is imperative to determine a level of exposure to occupational risks, as well as to perform occupational risk assessment especially in case of an accident on these plants caused by inadequate working conditions. Systematic examination of working conditions could improve occupational conditions within these plants, as well as the influence of working environment parameters on worker's mental and physical health and ability to work. Unfortunately, in our country, such tests have not been done in the last fifteen years.

Therefore, they should be used to create provide a clear image of the worker's exposure to occupational risk within these facilities, and trigger a systematic, regular and comprehensive examination of the parameters of the working environment.

The main occupational health hazards associated with operators working on wastewater treatment plant (WWTP) can be the following:

- Mechanical - working in a confined space at a height/depth of the different levels, etc.
- Physical - chemical character - chemicals, gases, fumes, noise, etc.
- Biological - microorganisms from wastewater and sludge, insects, etc.

Table 1 summarizes the most prominent occupational hazards associated with the activities performed by water treatment plant operators. [10]

**Table 1.** *Most prominent occupational hazards at water treatment plants*

| Potable water treatment | Wastewater treatment |
|---|---|
| Mineral acid (the pre-treatment intended for balancing the pH value), vapours of organic acid, ammonia fumes, aluminum sulfate, ozone, chlorine gas, sodium hypochlorite, nitrogen gas, (final treatment + water disinfection).<br>Standard laboratory compounds.<br>Work in a confined space at a height/depth of the different levels.<br>Occupational noise. | All harmful effects of chemical substances that occur during the drinking water treatment, with the addition of: phenol, hydrogen sulfide, tri-halo-methane, methane, etc. (In wastewaters treated in these facilities, there are about 200 identified chemicals to which workers may be exposed).<br>Work in a confined space at a height/depth of the different levels.<br>Occupational noise.<br>Non-comfortable odour.<br>Different pathogens.<br>Insects and other animals. |

The basic aim is to assess the risk to which workers - water treatment operators - are exposed to in water treatment plants (workplace, process and organization of work, the presence of physical, chemical and mechanical hazards, etc.), as well as to propose preventive measures to reduce the level of occupational risk.

Considering the fact that in Republic of Serbia there is no systematized evidence of occupational injuries by activities i.e. economy branches, it is not possible to display data related to this activity. For this reason, this section presents data related to occupational injuries in economy branch E - Water supply; wastewater management (sewage system), solid waste management and environmental remediation activities in the Republic of Croatia in 2014.

In the Republic of Croatia, a total of 13,929 occupational injuries occurred during working activities in the year 2014, while in the economy branch E - Water supply; wastewater management (sewage system), solid waste management and environmental remediation activities - 425 occupational injuries, which makes share of 3.05% of the total number of occupational injuries. According to the number of occupational injuries, this activity is ranked 11$^{th}$, out of 21 activities.

Table 2 shows data on occupational injuries in economy branch E - Water supply; wastewater management (sewage system), solid waste management and environmental remediation activities in the Republic of Croatia. [11]

**Table 2.** *Occupational injuries in economy branch E - Water supply; wastewater management (sewage system), solid waste management and environmental remediation activities in the Republic of Croatia*

| | Sector | Occupational injuries | | | |
|---|---|---|---|---|---|
| | | At workplace | On the way to work | Total | % |
| 1 | Potable water intake, purification activities, water distribution | 102 | 13 | 115 | 27.06 |
| 2 | Sewage system (wastewater collection and treatment) | 13 | 3 | 16 | 3.76 |
| 3 | Solid waste collection, waste treatment and disposal, reuse and recycle activities | 251 | 24 | 275 | 64.71 |
| 4 | Environmental remediation activities and other similar activities | 19 | 0 | 19 | 4.47 |
| | **Total:** | **385** | **40** | **425** | **100.00** |

Based on presented data, it can be concluded that the highest number of occupational injuries is recorded in the area of solid waste collection, waste treatment and disposal, reuse and recycle activities - 64.71%. Otherwise, in this area, employees are far more injured at the workplace (251) - 91.3% rather than on the way to work, or vice versa (24) - 8.7%. The second ranked is the potable water intake, purification activities and water distribution sector, with a share of occupational injuries of 27.06%, whereas in the sector of sewage system (wastewater collection and treatment) there is relatively little occupational injury share, i.e. only 3.76%. The fact is that the Republic of Croatia has very few operational facilities for wastewater treatment and, consequently, a small number of employees in this field, which explains the relatively small percentage of occupational injuries within this sector.

## PREVENTIVE MEASURES

The primary goals of implemented OSH system should be seen in the analysis of all jobs in an observed institution or organization in accordance with the current laws and bylaws. In order to define jobs with increased risk, which are subject to special legislative procedures, it is necessary to establish all occupational harms and workplace hazards and to compile all potential professional risks, demands, and workloads of workers, which stem from the job characteristics themselves, work activities, and work conditions, as well as occupational safety efficiency measures.

This is a multi-phase process which demands the responsible persons to assess and control occupational risks in an efficient and effective manner. Hazard assessment is an initial way to determine the most serious danger, and also, to define a priority. The priority is usually determined by taking into account the severity of events and the likelihood of occurrence. By assigning a priority list, or rating (ranking) list, priority activities can be effectively dedicated.

The following factors form the basis for defining a risk matrix:

Seriousness of exposure - severity of event and

The probability of occurrence - incident rate.

The results of the risk assessment are usually presented in the risk matrix. Risk matrix is an essential tool for the decision-making process regarding risk control. Otherwise, the risk can be calculated using the following formula:

$$\text{Risk} = \text{Likelihood} \times \text{Severity i.e.}$$

$$R = L \times S$$

while R, L and S are non-dimensional units.

Based on the knowledge of Likelihood and Severity, it is possible to construct a basic risk matrix, as shown in the Table 3.

**Table 3.** *Basic risk matrix*

| | | | | | | |
|---|---|---|---|---|---|---|
| Likelihood | 5 | 5 | 10 | 15 | 20 | 25 |
| | 4 | 4 | 8 | 12 | 16 | 20 |
| | 3 | 3 | 6 | 9 | 12 | 15 |
| | 2 | 2 | 4 | 6 | 8 | 10 |
| | 1 | 1 | 2 | 3 | 4 | 5 |
| Severity | | 1 | 2 | 3 | 4 | 5 |
| Risk levels | | Extreme risk level | | 15-25 | | |
| | | High risk level | | 8-14 | | |
| | | Moderate risk level | | 4-6 | | |
| | | Low risk level | | 1-3 | | |

Once the hazard has been identified, preventive measures can be taken to ensure that this information is taken into account in risk ranking process. The risk can be presented in various ways in terms of the distribution of risks within the company or at the workplace. In this sense, hazard identification represents the initial process for quantifying hazards and eliminating or reducing the risk of occupational injury/illness of workers as well as damage to property, equipment and immediate environment.

As previously stated, high-risk jobs and tasks are those that involve potential risks of injury and harmful health effects despite the implementation of specific occupational safety and health protective measures, since potential risks cannot be eliminated or minimized and cannot always be controlled.

In this sense, regarding the activities performed by water treatment operators, it is necessary to do the following:

1. Maintain good personal hygiene,
2. Improve all aspects of occupational health and safety, primarily based on ISO 45001 standard,
3. Implement other quality management systems (QMS) and environmental management system (EMS).

To prevent risks associated with chemical substances used in the plant, it is necessary to do the following:

1. List all the dangerous chemicals and make a description of the impact,
2. Develop and implement a control program.

Dangerous activities include, but are not strictly limited to:

1. Work in a closed confined spaces, such as:
   - manholes,
   - sedimentation tanks, sand traps, aeration basins, etc.,
   - pumping stations,
   - tunnels.
2. Lifting heavy objects.
3. Using ladders and steps.
4. Work in an area with fumes.
5. Work with electrical installations.

By using the risk matrix tool, it is possible to construct occupational risk matrix for illustrative working operations, as shown in Table 4.

**Table 4.** *Risk matrix – water supply and sewerage treatment activities/units*

| Stage/operation | Occupational hazard | Adverse event | Harmful effect | Risk level | | |
|---|---|---|---|---|---|---|
| | | | | P | S | Score |
| Potable water intake | Confined spaces | Choking, drowning | Injury, fatality | 2 | 3 | 6 |
| | Work at height | Falling, slippery | Injury, fatality | 3 | 3 | 9 |
| | Laboratory test | Breaking | Injury | 1 | 3 | 3 |
| | Disinfection | Chlorine inhalation | Fatality | 4 | 5 | 20 |
| Water treatment | Electrical inst. | Electric shock | Injury, fatality | 3 | 4 | 12 |
| | Heavy objects | Breaking | Injury | 3 | 3 | 9 |
| | Work at height | Falling | Injury | 2 | 4 | 8 |
| Water distribution | Confined spaces | Choking, slippery | Injury | 5 | 1 | 5 |
| | Heavy objects | Breaking | Injury | 5 | 1 | 5 |
| Wastewater treatment | Area with fumes | Choking | Nuisance | 5 | 1 | 5 |
| | Heavy objects | Breaking | Injury | 3 | 3 | 9 |
| | Work at height | Falling | Injury | 2 | 4 | 8 |
| | Electrical inst. | Electric shock | Injury, fatality | 3 | 4 | 12 |
| | Infective areas | Infective contact | Diseases | 4 | 4 | 16 |

After the matrix-based risk identification, the next phase refers to defining preventive/protective measures. General protection measures include, but are not strictly limited to:

- safety fences,
- aspects of protection against fire and explosion,
- safety labels,
- adequate ventilation,
- adequate lighting,
- appropriate handling space,
- easy access,
- the appropriate operating temperature.

For maximum protection, employees who work in the plant can additionally received vaccines against hepatitis A and B, influenza, measles, mumps, lung disease, rubella, tetanus, etc.

## CONCLUSION

Complex dynamic systems, such as a potable water treatment and centralized wastewater treatment plant, represent the systems that consist of the large number of activities and processes that interact with each other, and, as a rule, are always in a condition of slight oscillations of the pre-defined process parameters. In wastewater treatment systems, such deviations are related to the input water quality and the uneven mass flow rates over time. Bearing in mind, the operator of the plant for centralized treatment of used water often has to react to situations that deviate significantly from the project defined conditions of the plant. The management of deviations from the desired process parameters is the basic reason for the introduction of advanced occupational safety systems. The advantages of using these systems to control the processes in water treatment facilities are twofold: there is a higher quality of output values in terms of saving time, energy and material, and safer and healthier working environment.

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## BIOGRAPHY

**Dejan Vasović** was born in Prokuplje, Serbia, in 1982.
He received the diploma in environmental protection engineering and the Magister of technical sciences degree in the same field from the University of Nis, Faculty of Occupational Safety in Niš. Afterwards, within the same faculty, he obtained the PhD in technical sciences - environmental protection. His main areas of research include environmental protection with particular regard to water resources management and protection, environmental capacity, environmental safety and security, etc. He is currently working as an assistant professor at the Faculty of Occupational Safety in Nis, University of Nis.

# USLOVI RADA NA POSTROJENJIMA ZA TRETMAN VODA: AKTIVNOSTI, OPASNOSTI I MERE ZAŠTITE

***Vasović Dejan, Stanković Sandra, Vranjanac Žarko***

**Rezime:** *U operativnom smislu, postrojenja za tretman voda kao i operateri koji na njima rade, predstavljaju osnovu za dostizanje dobrog statusa kvaliteta voda. U tom smislu je i osnovni cilj ovog rada usmeren ka oceni oceni uslova rada i rizika kojim operateri mogu biti izloženi, kao i merama zaštite kojime se može redukovati profesionalni rizik. Primenjena metodologija se sastoji od sistemske analize, kao i detaljne analize sadržaja dostupne naučno-stručne literature. Najvažniji zaključci se odnose na definisanje pogodnog sistema upravljanja profesionalnim rizikom na ovakvim postrojenjima čijom primenom se postiže dvostruki efekat: viši kvalitet tretirane voda tokom kraćeg vremenskog perioda i uz manji utrošak materijala i energije ali i bezbednije i zdravije uslove rada.*

**Ključne reči:** postrojenja za tretman voda, opasnosti, profesionalni rizik, mere zaštite.